[10] Waldvogel FA, Medoff G, Swartz MN. Osteomyelitis: a review of clinical features, therapeutic considerations and unusual aspects (second of three parts). N Engl J Med. 1970;282:260–266. doi:10.1056/NEJM197001292820507.
[11] Liu RW, Abaza H, Mehta P, Bauer J, Cooperman DR, Gilmore A. Intravenous versus oral outpatient antibiotic therapy for pediatric acute osteomyelitis. Iowa Orthop J. 2013;33:208–212.
[12] Scott RJ, Christofersen MR, Robertson WW, Davidson RS, Rankin L, Drummond DS. Acute osteomyelitis in children: a review of 116 cases. J Pediatr Orthop. 1990;10:649–652.
[13] Goergens ED, McEvoy A, Watson M, Barrett IR. Acute osteomyelitis and septic arthritis in children. J Paediatr Child Health. 2005;41:59–62. doi:10.1111/j.1440-1754.2005.00538.x.
[14] Mahmoudi S, Pourakbari B, Borhani K, Khodabandeh M, Valian SK, Aziz-Ahari A, et al. Acute osteomyelitis and septic arthritis in children: a referral hospital-based study in Iran. Wien Med Wochenschr. 2017;167:259–263. doi:10.1007/s10354-017-0583-1.
[15] O'Brien T, McManus F, MacAuley PH, Ennis JT. Acute haematogenous osteomyelitis. J Bone Joint Surg Br. 1982;64:450–453.
[16] Cole WG, Dalziel RE, Leitl S. Treatment of acute osteomyelitis in childhood. J Bone Joint Surg Br. 1982;64:218–223.
[17] Lauschke FH, Frey CT. Hematogenous osteomyelitis in infants and children in the northwestern region of Namibia. Management and two-year results. J Bone Joint Surg Am. 1994;76:502–510.
[18] Labbé J-L, Peres O, Leclair O, Goulon R, Scemama P, Jourdel F, et al. Acute osteomyelitis in children: the pathogenesis revisited? Orthop Traumatol Surg Res. 2010;96:268–275. doi:10.1016/j.otsr.2009.12.012.
[19] Riise ØR, Kirkhus E, Handeland KS, Flatø B, Reiseter T, Cvancarova M, et al. Childhood osteomyelitis-incidence and differentiation from other acute onset musculoskeletal features in a population-based study. BMC Pediatr. 2008;8:45. doi:10.1186/1471-2431-8-45.
[20] Jagodzinski NA, Kanwar R, Graham K, Bache CE. Prospective evaluation of a shortened regimen of treatment for acute osteomyelitis and septic arthritis in children. J Pediatr Orthop. 2009;29:518–525. doi:10.1097/BPO.0b013e3181ab472d.
[21] Street M, Puna R, Huang M, Crawford H. Pediatric acute hematogenous osteomyelitis. J Pediatr Orthop. 2015;35:634–639. doi:10.1097/BPO.0000000000000332.
[22] Romanò CL, Romanò D, Logoluso N, Drago L. Bone and joint infections in adults: a comprehensive classification proposal. Eur Orthop Traumatol. 2011;1:207–217. doi:10.1007/s12570-011-0056-8.
[23] Prieto-Pérez L, Pérez-Tanoira R, Petkova-Saiz E, Pérez-Jorge C, Lopez-Rodriguez C, Alvarez-Alvarez B, et al. Osteomyelitis: a descriptive study. Clin Orthop Surg. 2014;6:20–25. doi:10.4055/cios.2014.6.1.20.
[24] May JW, Gallico GG, Lukash FN. Microvascular transfer of free tissue for closure of bone wounds of the distal lower extremity. N Engl J Med. 1982;306:253–257. doi:10.1056/NEJM198202043060501.
[25] Weiland AJ, Moore JR, Daniel RK. The efficacy of free tissue transfer in the treatment of osteomyelitis. J Bone Joint Surg Am. 1984;66:181–193.
[26] Jones HW, Harrison JW, Bates J, Evans GA, Lubega N. Radiologic classification of chronic hematogenous osteomyelitis in children. J Pediatr Orthop. 2009;29:822–827. doi:10.1097/BPO.0b013e3181b76933.
[27] Marais LC, Ferreira N, Aldous C, Le Roux TLB. The outcome of treatment of chronic osteomyelitis according to an integrated approach. Strategies Trauma Limb Reconstr. 2016;11:135–142. doi:10.1007/s11751-016-0259-1.
[28] Gordon L, Chiu EJ. Treatment of infected non-unions and segmental defects of the tibia with staged microvascular muscle transplantation and bone-grafting. J Bone Joint Surg Am. 1988;70:377–386.
[29] Hotchen AJ, McNally MA, Sendi P. The classification of long bone osteomyelitis: a systemic review of the literature. J Bone Jt Infect. 2017;2:167–174. doi:10.7150/jbji.21050.

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QUESTION 5: Is synovial fluid or fracture hematoma always aseptic? If not, could this play a role in acute infection or periprosthetic joint infection (PJI) after open reduction and internal fixation (ORIF)?

RECOMMENDATION: Fracture hematoma is not always aseptic. It is unknown if synovial fluid is always aseptic. In addition, it is unclear if this plays a role in acute infection or fracture-related infection (FRI) after ORIF.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 95%, Disagree: 5%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

The association between soft-tissue conditions and infection has been well-known since the 1970s, when Gustilo and Anderson described how the major risk factor for post-traumatic infection following open fracture was the quality of the soft tissue envelope [1]. More recent evidence has demonstrated how traumatized host tissue can result in altered vascularization, decreased perfusion, increased endothelial permeability and decreased oxygenation; all of which can compromise the body's innate ability to resist local infection [1,2]. The prevailing theory of infection is that it is secondary to inoculation of pathologic microorganisms in traumatized tissues; however, it is unclear how infection occurs in closed trauma if there is no bacterial contamination through an open wound [2]. Some have questioned the common belief that synovial fluid and fracture hematoma is always aseptic based on evidence from other surgical fields that demonstrated how bacterial balance within presumably clean soft tissues affects the likelihood of soft tissue healing versus infection [3].

Two recent studies explored if fracture hematoma or callus was aseptic. In contrast to the prevailing view that these tissues are always clean, both studies found that 14 to 40% of the deep tissues grew bacteria when cultured, but no study has replicated these findings with synovial fluid. Szczesny et al. used conventional and molecular bacterial detection methods to determine if bacteria colonized lower limb soft tissues and bone following closed fractures in 71 patients. Cultures of fracture callus were positive in 26.7% of patients and bacterial rRNA was isolated in 41% of patients [4]. Similarly, Font-Vizcarra et al. evaluated the presence of positive cultures from hematoma in 109 patients with femoral neck fractures. They found that fracture hematoma was positive in 31.2% of all patients [2]. In both studies, the most common cultured organism was *S. epidermidis*. Based on recent basic science data, the presumed mechanism of infection of the deep tissues was that high-stress conditions resulted in decreased ability to contain skin and mucosal flora, leading to seeding of traumatized soft tissues/hematoma by lymphatic spread or transient bacteremia [1,2,4].

Although there is good evidence that fracture hematoma is not always aseptic, it remains unclear if the bacteria within the deep tissues play a role in acute infection or PJI after ORIF. Font-Vizcarra et al. did not find that culture positivity was a risk factor for early post-traumatic infection unless the specimen grew gram-negative rods [2]. Similarly, positive cultures from the fracture callus was not associated with non-union following closed tibia or femur fractures

[4]. Based on this data, it is unknown what bacterial load is necessary to evoke infection and overwhelm the host response [3].

REFERENCES

[1] Kälicke T, Schlegel U, Printzen G, Schneider E, Muhr G, Arens S. Influence of a standardized closed soft tissue trauma on resistance to local infection. An experimental study in rats. J Orthop Res. 2003;21:373–378. doi:10.1016/S0736-0266(02)00149-3.

[2] Font-Vizcarra L, Zumbado A, García S, Bosch J, Mensa J, Soriano A. Relationship between haematoma in femoral neck fractures contamination and early postoperative prosthetic joint infection. Injury. 2011;42:200–203. doi:10.1016/j.injury.2010.09.006.

[3] Robson MC, Mannari RJ, Smith PD, Payne WG. Maintenance of wound bacterial balance. Am J Surg. 1999;178:399–402.

[4] Szczêsny G, Interewicz B, Swoboda-Kopeć E, Olszewski WL, Górecki A, Wasilewski P. Bacteriology of callus of closed fractures of tibia and femur: J Trauma Inj Infect Crit Care. 2008;65:837–842. doi:10.1097/TA.0b013e3181469d44.

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QUESTION 6: What is the relationship between implanted metal and colonization under a vacuum-assisted closure (VAC) in open fractures?

RECOMMENDATION: The use of negative pressure wound therapy (NPWT or VAC) over exposed orthopaedic implants has been reported but its role remains unknown. Furthermore, no evidence exists regarding the effect of NPWT on the colonization of metal implants in open fractures. Further research is required to provide more insight into this question.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

NPWT has emerged as a promising modality for the treatment of open fracture wounds between operative debridements and delayed wound closure or coverage [1,2]. Traditional management of fractures with soft tissue defects included wet-to-dry dressings with the risk of wound contamination and infection rates reportedly as high as 50% [3]. In addition to providing a semiocclusive dressing, NPWT mechanisms of action include stabilization of the wound environment, reduction of wound edema, improvement of tissue perfusion and stimulation of cells at the wound surface [1]. While initial randomized controlled trials (RCTs) favored NPWT in reducing infection in open fractures [4], a recent Cochrane database review found little difference compared to standard dressings [5]. The ability to successfully clear the infection may be tied to the VAC's effect on the wound bioburden [6].

A recent systematic review identified 24 studies investigating the topic of bacterial growth and NPWT, but none contained exposed implants [6]. The authors identified 10 experimental studies, 4 RCTs, 6 clinical studies and 4 using an instillation VAC system [6]. Of the RCTs, only one quantified bacterial proliferation and performed species analysis. Moues et al. found that NPWT selectively reduced non-fermentative gram-negative bacilli (NFGNB) but increased the proliferation of *S. aureus* [7]. The other three RCTs found no difference with the NPWT in regard to reduced bacterial growth or number of positive cultures [6]. The authors of this review concluded that there was a lack of concensus in the literature if the NPWT increases, decreases, or has no effect on the wound bioburden.

Perhaps even less is known about the relationship between implanted metal and colonization under a NPWT device in open fractures, as no studies have investigated this topic. The main reason is that contemporary "fix and flap" open fracture treatment does not advocate the use of NPWT devices over exposed metal. Some cases where this treatment might be an option include: (a) open fracture treated initially with hardware that undergoes wound breakdown, (b) if hardware removal at debridement is not feasible or would drastically compromise limb stability or (c) the patient is not a medical candidate for additional soft tissue coverage or additional surgery [8]. In such cases, the recommendation is to perform a secondary early coverage with local or distant flaps, but NPWT is not an option for definitive treatment. While case reports and small series have described the use of a wound VAC over exposed orthopaedic hardware in other instances [8–13], no studies have included bacterial proliferation or speciation analysis.

In conclusion, while there is evidence supporting the safety and efficacy of NPWT over exposed metal for a period of time without infectious complications, there are no published studies investigating this in associaton with open fractures. While the use of NPWT in open fractures with exposed metal is a viable option, it is not a part of the contemporary treatment of open fractures. Further research and study into implant colonization under a NPWT will be required before such a practice can be routinely recommended.

REFERENCES

[1] Streubel PN, Stinner DJ, Obremskey WT. Use of negative-pressure wound therapy in orthopaedic trauma. J Am Acad Orthop Surg. 2012;20:564–574. doi:10.5435/JAAOS-20-09-564.

[2] Krug E, Berg L, Lee C, Hudson D, Birke-Sorensen H, Depoorter M, et al. Evidence-based recommendations for the use of negative pressure wound therapy in traumatic wounds and reconstructive surgery: steps towards an international consensus. Injury. 2011;42 Suppl 1:S1–S12. doi:10.1016/S0020-1383(11)00041-6.

[3] Dedmond BT, Kortesis B, Punger K, Simpson J, Argenta J, Kulp B, et al. The use of negative-pressure wound therapy (NPWT) in the temporary treatment of soft-tissue injuries associated with high-energy open tibial shaft fractures. J Orthop Trauma. 2007;21:11–17. doi:10.1097/BOT.0b013e31802cbc54.

[4] Stannard JP, Volgas DA, Stewart R, McGwin G, Alonso JE. Negative pressure wound therapy after severe open fractures: a prospective randomized study. J Orthop Trauma. 2009;23:552–557. doi:10.1097/BOT.0b013e31811a2e2b6.

[5] Iheozor-Ejiofor Z, Newton K, Dumville JC, Costa ML, Norman G, Bruce J. Negative pressure wound therapy for open traumatic wounds. Cochrane Database Syst Rev. 2018;7:CD012522. doi:10.1002/14651858.CD012522.pub2.

[6] Glass GE, Murphy GRF, Nanchahal J. Does negative-pressure wound therapy influence subjacent bacterial growth? A systematic review. J Plast Reconstr Aesthetic Surg. 2017;70:1028–1037. doi:10.1016/j.bjps.2017.05.027.